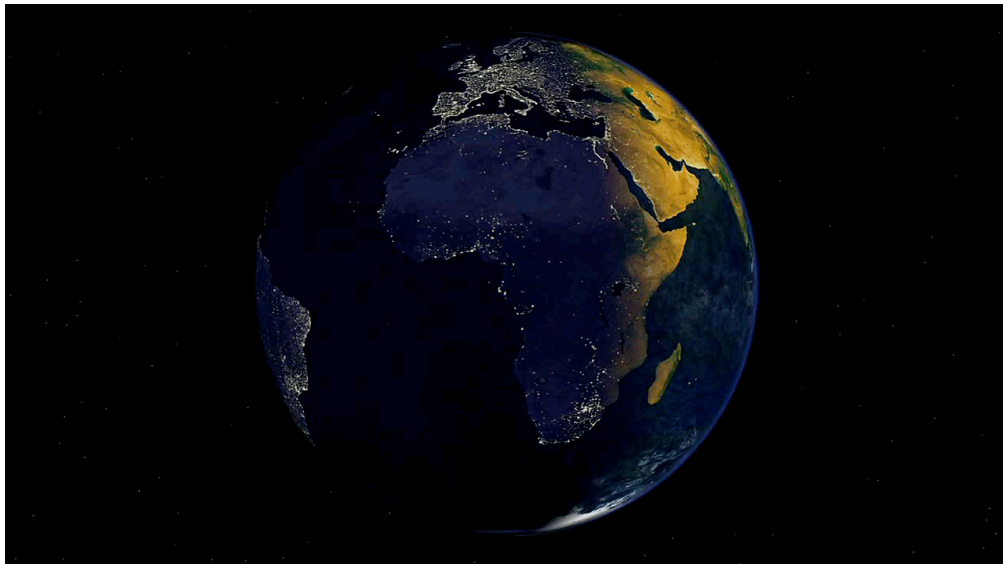
Potential Drivers of Urban Heat Islands in the Northeast USA

Ping Zhang[1,2], Marc Imhoff[1], Robert Wolfe[1], and Lahouari Bounoua[1]

1. Hydrospheric and Biospheric Sciences Laboratory Research, NASA's Goddard Space Flight Center
2. Earth Resource Technology Inc., Laurel, MD

1. I would like to introduce our team leader Dr. Marc Imhoff, and a key member Robert Wolfe who are sitting at the first row. They have been critically involved in this research and would love to help answer questions regarding this research

Why Cities Matter



- Already about 50 percent of people live in cities
- That number will increase to 80 percent by 2030

1. Urban area only covers 3% of our land surface- very small portion.
2. general public should be interested in urban heat islands because of the fact that it's where most of the people live and in the next 50 years, we're going to see 80% of the global population living in cities. And the urban heat island matters for everything from health, like asthma and heart conditions, to how much heating and air conditioning you need to use to cool or heat your living space
3. Urban area alters weather and climate with feedbacks that influence human health and energy consumption, and those two things alone are enough to drive world-wide interests.

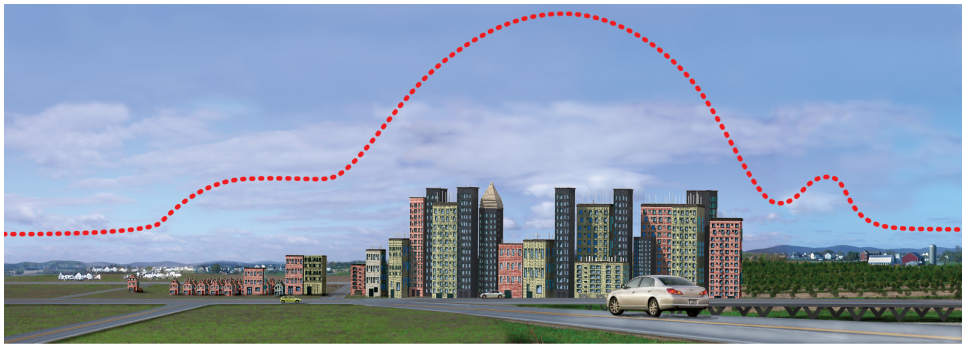
The Centers for Disease Control and Prevention estimates that from 1979-2003, excessive heat exposure contributed to more than 8000 premature deaths in the US. Exceeds the number of mortalities resulting from hurricanes, lighting, tornadoes, floods, and earthquakes combined.

Summer UHI is more significant than winter UHI. People will need to use more AC to cool their houses.

UHI will change the pheonology of plants as well as the habitat of some animals.

What underlies differences between urban heat islands?

- Cities in forested areas have strong heat islands
- If background ecology is the same, larger cities have stronger heat islands
- **Newest finding:** Densely developed, aggregated cities produce stronger urban heat islands than sprawling cities with less development density



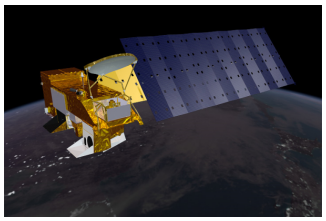
When we build urban area, replacing vegetated surface or soil surface with impervious surface such as paving material and building material, the temperature will increase and generate a temperature difference between the urban area and surrounding non-urban area.

Our Approach

- Most comparisons of heat islands have relied on ground-based air temperature measurements

vs.

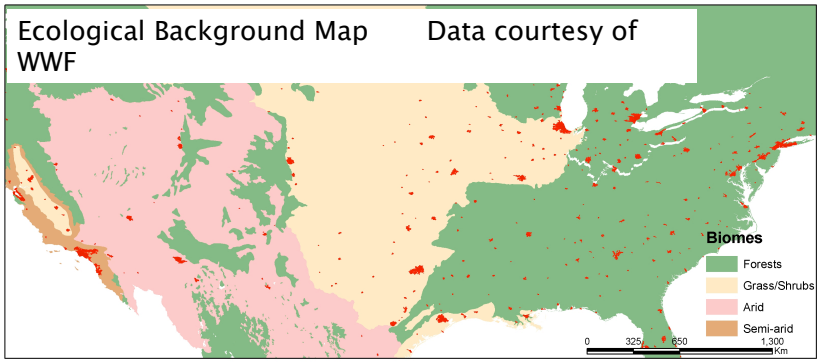
- We used satellites data, which offer more uniform measurements, instead.



Air temperature is focus in characterizing specific city. It is hard to intercomparison between cities.

Our interest is in the surface UHI effect because the conversion of surfaces more directly links to the alteration of a broader suite of physical and biophysical processes related to the intensity and trajectory of land cover change.

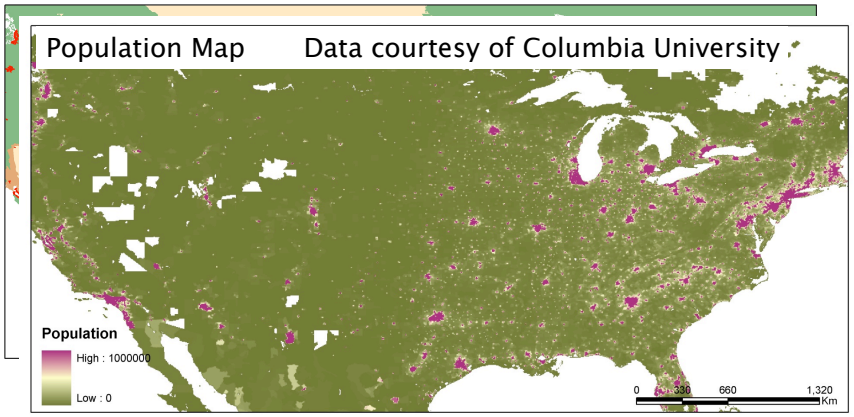
Data and Methodology



• Analyzed databases of city size, area, background ecology, surface temperatures, and impervious surface areas (satellite measurement that shows the intensity of development) from regional to global scales
• Most recently compared 42 cities in the Northeast USA to get an even higher-resolution understanding of what causes heat islands to vary

We use variety of satellite data, including LST from MODIS and impervious surface are from landsat satellite, ISA basically tell us how much building material on the land surface. Over continental scale and global scale, ecological context.

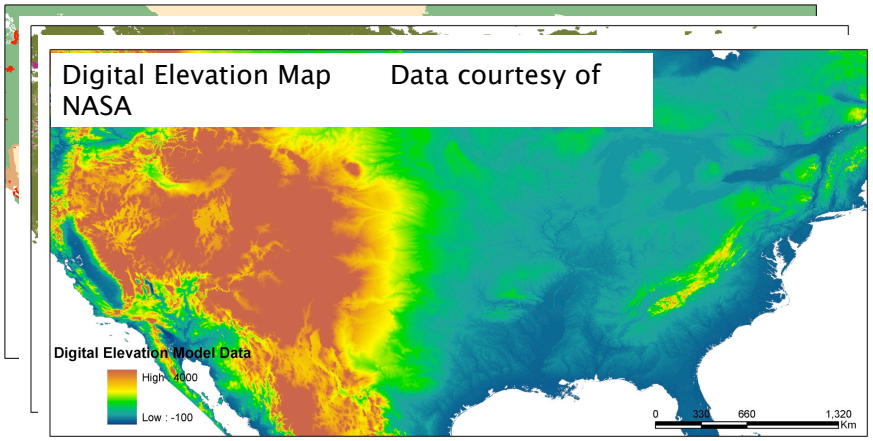
Data and Methodology



• Analyzed databases of city size, area, background ecology, surface temperatures, and impervious surface areas (satellite measurement that shows the intensity of development) from regional to global scales
• Most recently compared 42 cities in the Northeast USA to get an even higher-resolution understanding of what causes heat islands to vary

Co register all the data from different sensors at multiple years, for the first time, we look at the city over different continents how UHI vary in sizes, locations, shapes.

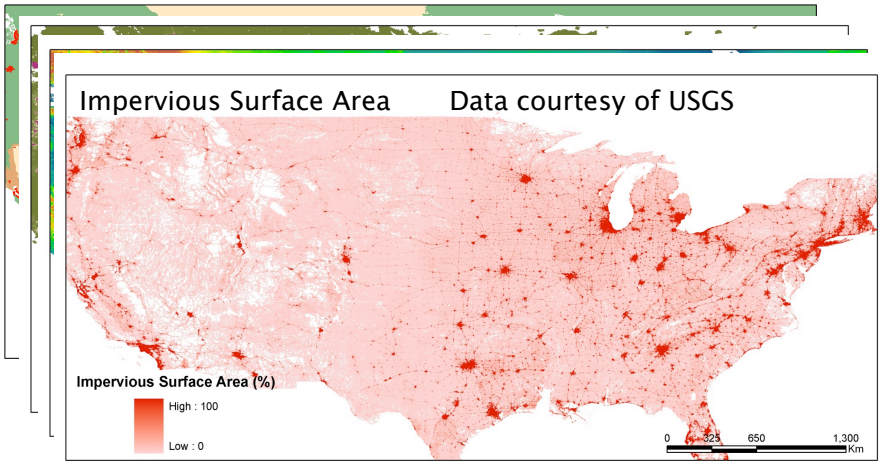
Data and Methodology



• Analyzed databases of city size, area, background ecology, surface temperatures, and impervious surface areas (satellite measurement that shows the intensity of development) from regional to global scales
• Most recently compared 42 cities in the Northeast USA to get an even higher-resolution understanding of what causes heat islands to vary

Co register all the data from different sensors at multiple years, for the first time, we look at the city over different continents how UHI vary in sizes, locations, shapes.

Data and Methodology

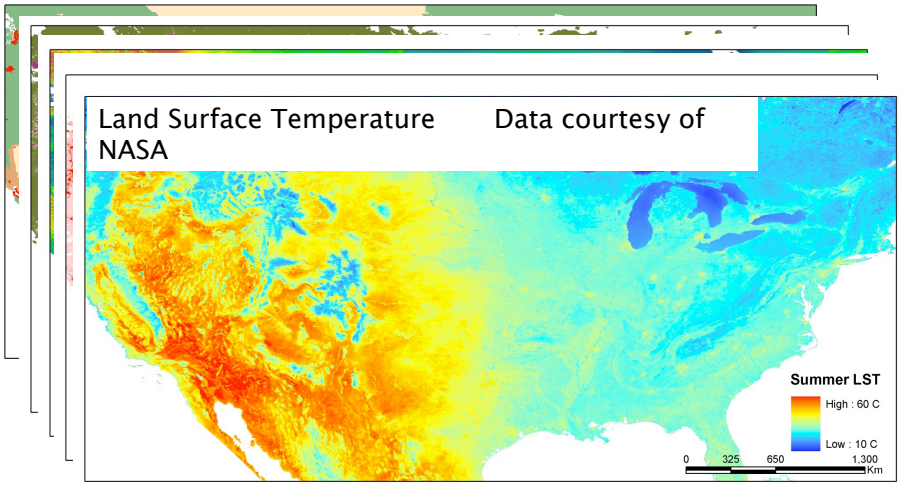


• Analyzed databases of city size, area, background ecology, surface temperatures, and impervious surface areas (satellite measurement that shows the intensity of development) from regional to global scales
• Most recently compared 42 cities in the Northeast USA to get an even higher-resolution understanding of what causes heat islands to vary

Impervious surface is the density of the urban surface. Asphalt absorb heat and is hotter. Vegetation cover, like trees they will cool the temperature through shading and transpiration.

Co register all the data from different sensors at multiple years, for the first time, we look at the city over different continents how UHI vary in sizes, locations, shapes.

Data and Methodology

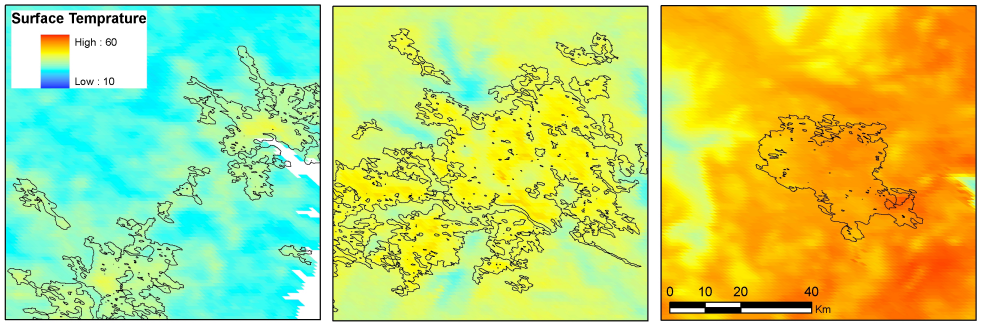


• Analyzed databases of city size, area, background ecology, surface temperatures, and impervious surface areas (satellite measurement that shows the intensity of development) from regional to global scales
• Most recently compared 42 cities in the Northeast USA to get an even higher-resolution understanding of what causes heat islands to vary

Co register all the data from different sensors at multiple years, for the first time, we look at the city over different continents how UHI vary in sizes, locations, shapes.

Finding #1: Background Ecology Matters

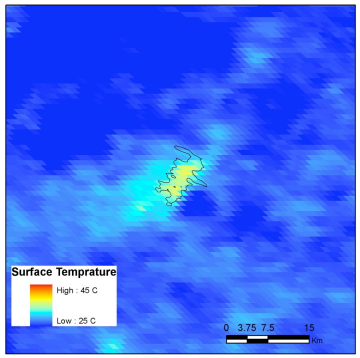
Baltimore-DC area (Forest) | Dallas, Texas (Grass) | Las Vegas, Nevada (Desert)

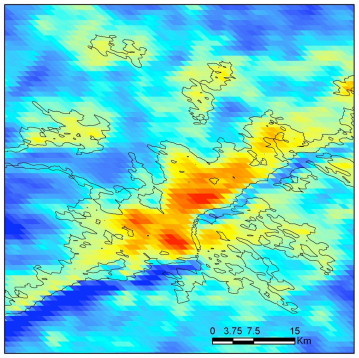


- **Cities in forested areas have much larger heat islands than cities in arid areas.**
- **Cities in grassy or agricultural areas are somewhere in the middle**

Urbanization initiates a different heating process between impervious surfaces, generally made of asphalt and other heat absorbing materials, and the surrounding naturally vegetated landscapes. The temperature difference between urban cores and rural zones is driven by the surrounding land use type. Our results show the background ecological context is a statistically significant modulator of the diurnal and seasonal UHI at continental and global scales. Here are 3 examples cities from different background ecology. Forest, around 10C, grass 5-6C, desert weak and sometime heat sink.

Finding #2: Size Matters





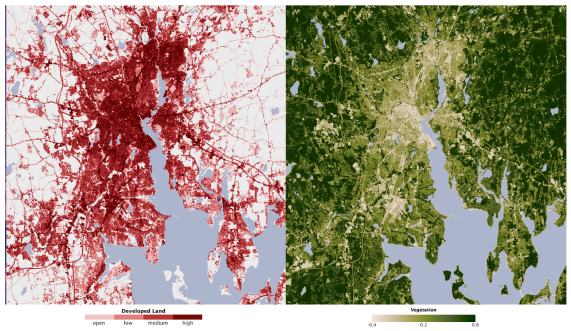
City:	Lynchburg, VA	Philadelphia, PA
Pop:	7000	1563000
Size:	29 km^2 (11.2mi^2)	790 km^2 (11.2mi^2)
Heat Island:	5.5 C (9.9F)	11.7 C (21.1F)

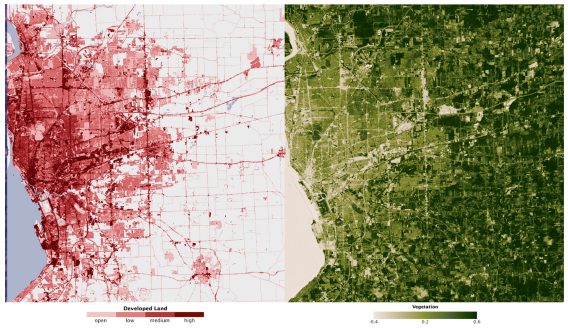
Not a surprise: Bigger cities have bigger heat islands!

With in the same forest ecological context, bigger cities have bigger heat islands in terms of both population and area. Using about 40 sample cities in Northeast USA, our results show that the UHI is logarithm-linear related to the population or size of the transformed area of the urban.

Newest Finding #3: Development Pattern Matters

Providence, Rhode Island
Urban area: 355 km^2(137 mi^2)
Tree cover at rural: 84%
UHI=12 C (21.6 F)
Buffalo, New York
Urban area: 320 km^2 (124 mi^2)
Tree cover at rural: 15%
UHI=7 C (12.6 F)





- **More compact, densely-developed cities have warmer urban area**
- **Increased tree cover at surrounding rural areas makes these areas cooler**
- **Providence has a stronger urban heat island**

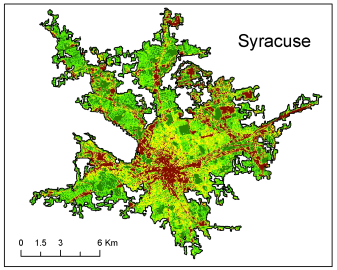
We have chose two cities with the same ecological context, and similar sizes from Northeast USA: Providence, Rhode Island, and Buffalo, New York.

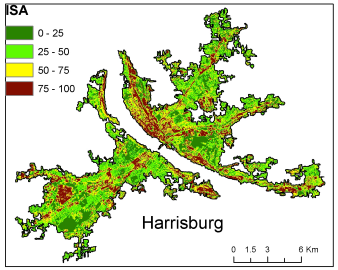
Our results show that development pattern is critical to explain the difference of urban heat island among cities with similar sizes and ecological context

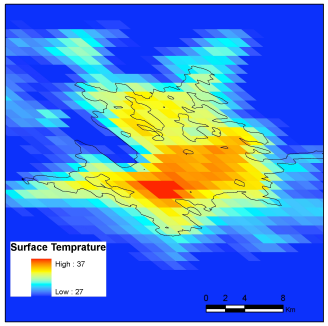
Conclusions

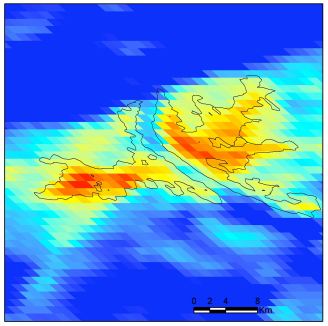
- Forest cities have stronger urban heat islands than cities in other ecological context.
- Within the same ecological context, the larger the city, the stronger the urban heat island.
- Densely developed, aggregated cities produce stronger urban heat island than sprawling cities with less development density.
- Next step: modeling effort to simulate heat, water, and energy flux changes with

Urban Shapes and Urban Heat Island (backup 1)





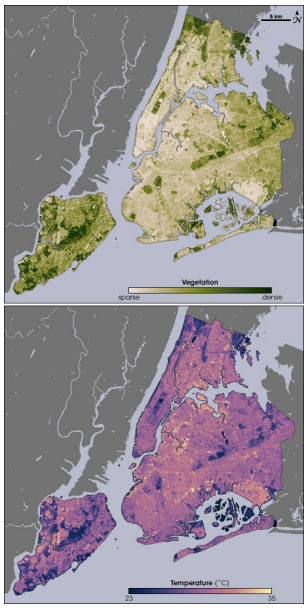




Syracuse
Area:152 km^2
58.7mi^2
UHI: 10.6C
19 F

Harrisburg
Area:152 km^2
58.7 mi^2
UHI: 7.6 C
13.7 F

Urban Heat island Mitigation (backup 2)



A building in Portland, Oregon (Portland Bureau of Environmental Services)

- Increasing tree and vegetative cover
- Installing green roofs (also called "rooftop gardens" or "eco-roofs")
- Installing cool—mainly reflective—roofs
- Using cool pavements

Reduced energy use: Green roofs absorb heat and act as insulators for buildings, reducing energy needed to provide cooling and heating.
Reduced air pollution and greenhouse gas emissions: By lowering air conditioning demand, green roofs can decrease the production of associated air pollution and greenhouse gas emissions. Vegetation can also remove air pollutants and greenhouse gas emissions through dry deposition and carbon sequestration and storage.

Backup 3

- Examples of USA cities with large UHI
  - Baltimore-DC, Philadelphia, Boston, Providence
- Examples of world cities with large UHI
  - Sendai, Japan; Philadelphia, USA; Ottawa, Canada; Quito, Ecuador; Paris, France